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10/041,064	01/09/2002	Jin Yu		1966

7590 12/02/2004

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EXAMINER
CURS, NATHAN M

ART UNIT	PAPER NUMBER
2633	

DATE MAILED: 12/02/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)
	10/041,064	YU, JIN
	Examiner	**Art Unit**
	Nathan Curs	2633

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *09 January 2002*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-8* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-8* is/are rejected.

7)☒ Claim(s) *1-8* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *09 January 2002* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

Oath/Declaration

1. The oath or declaration is defective. A new oath or declaration in compliance with 37 CFR 1.67(a) identifying this application by application number and filing date is required. See MPEP §§ 602.01 and 602.02.

The oath or declaration is defective for the following reasons:

- It does not state that the person making the oath or declaration believes the named inventor or inventors to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.
- It does not identify the mailing address of each inventor. A mailing address is an address at which an inventor customarily receives his or her mail and may be either a home or business address. The mailing address should include the ZIP Code designation. The mailing address may be provided in an application data sheet or a supplemental oath or declaration. See 37 CFR 1.63(c) and 37 CFR 1.76.
- The specification to which the oath or declaration is directed has not been adequately identified. See MPEP § 602.
- It does not state that the person making the oath or declaration has reviewed and understands the contents of the specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration.
- It does not state that the person making the oath or declaration acknowledges the duty to disclose to the Office all information known to the person to be material to patentability as defined in 37 CFR 1.56.
- The clause regarding "willful false statements ..." required by 37 CFR 1.68 has been omitted.
- It does not identify the citizenship of each inventor.
- It does not identify the city and either state or foreign country of residence of each inventor. The residence information may be provided on either on an application data sheet or supplemental oath or declaration.
- It was not executed in accordance with either 37 CFR 1.66 or 1.68.

Drawings

2. The drawings are objected to because the blank boxes in the figures should be labeled. Corrected drawing sheets in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. The figure or figure number of an amended drawing should not be labeled as "amended." If a drawing figure is to be canceled, the appropriate figure must be removed from the replacement sheet, and where necessary, the remaining figures must be renumbered and appropriate changes made to the brief description of the several views of the drawings for consistency. Additional replacement sheets may be necessary to show the renumbering of the remaining figures. The replacement sheet(s) should be labeled "Replacement Sheet" in the page header (as per 37 CFR 1.84(c)) so as not to obstruct any portion of the drawing figures. If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

Specification

3. The abstract of the disclosure is objected to because it contains several grammatical errors. Correction is required. See MPEP § 608.01(b).

Claim Objections

4. Claim 1 is objected to because of the following informalities: "see Fig. 1, 2" should be deleted. Appropriate correction is required.

5. Claims 1-8 are objected to because of the following informalities: there are multiple grammatical errors in the claims. Appropriate correction is required.

Claim Rejections - 35 USC § 112

6. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

7. Claims 4-8 are rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

Claim 4 recites the limitation "the entire band". There is insufficient antecedent basis for these limitations in the claim.

Further, claim 4 has different limitations with the claim apparently each dependent on different claims. Therefore the dependency of the claim is not clear.

Claim 5 recites the limitation "Channel multiplex device in claim 1". There is insufficient antecedent basis for these limitations in the claim.

Claim 6 recites the limitation "channel de-/multiplexing device", "the first stage", "the entire band of claim 1", "the second stage", "the trunk port" and "the small optical path between the first and the second stage". There is insufficient antecedent basis for these limitations in the claim.

Further, claim 6 mentions dependency to both claims 1 and 5. Therefore the dependency of the claim is unclear.

Claim 7 recites a limitation that is described within the claim as "conventional". Therefore, it's not clear what the applicant's limitation of the claimed invention is, since a disclosure of a feature as conventional means that the feature was well known in the art at the

time of the invention; there the feature would have been obvious to one of ordinary skill in the art at the time of the invention.

Claim 8 recites the limitation “the band and bandwidth of each semiconductor laser amplifier in claim 6” and "its small band”. There is insufficient antecedent basis for these limitations in the claim.

Claim Rejections - 35 USC § 102

8. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a) the invention was known or used by others in this country, or patented or described in a printed publication in this or a foreign country, before the invention thereof by the applicant for a patent.

9. Claims 1 and 5 are rejected under 35 U.S.C. 102(a) as being anticipated by Das et al. (http://www.ofsoptics.com/resources/documents/coarsewdm_20gb.pdf, August 2001).

Regarding claim 1, Das et al. disclose an optical CWDM system of large capacity, comprising: A plurality of optical transmitters to send data from local terminal to remote site (fig. 2, elements Node TX); A plurality of optical receiving port from remote sites (fig. 2, elements Node RX); Trunk output port linked to remote node of network (fig. 2, element Secondary Hub); Trunk input port linked from remote node of network (fig. 2, element Primary Hub); Multiplexing device to combine multiple local optical channels into the trunk output port (fig. 2, element 8x1 Mux); De-multiplex device to extract each channel in trunk input port to its channel port (fig. 2, element 1x8 DeMux) (see also page 850, Introduction section and page 851, Generic CWDM Architecture section);

Regarding claim 5, Das et al. disclose that the channel multiplex device in claim 1 has the same construct as de-multiplex device but the light traveling direction is reverse (fig. 2 and page 852, 1st full paragraph).

Claim Rejections - 35 USC § 103

10. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

11. Claims 2 and 3 are rejected under 35 U.S.C. 103(a) as being unpatentable over Das et al. (http://www.ofsoptics.com/resources/documents/coarsewdm_20gb.pdf, August 2001) in view of Eichenbaum et al. (http://www.ofsoptics.com/resources/documents/economics_wdm_20.pdf, August 2001).

Regarding claim 2, Das et al. disclose that there is a laser in each transmitter of claim 1, and serves as a carrier for data transmission (page 850, Introduction section), but does not disclose that the laser is a semiconductor DFB laser. Eichenbaum et al. disclose a CWDM system with the same waveband and wavelength spacing as that of the Das et al. system, and disclose using cost efficient semiconductor DFB source lasers that do not require cooling (page 1444, Introduction section, 2nd paragraph). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the DFB source lasers in the system of Das et al. due to their cost efficiency and lack of need for cooling, as taught by Eichenbaum et al.

Regarding claim 3, the combination of Das et al. and Eichenbaum et al. disclose the system of claim 2, and that all laser units are without temperature control (Eichenbaum et al.: page 1444, Introduction section, 2nd paragraph).

12. Claims 4, 6 and 8 are rejected under 35 U.S.C. 103(a) as being unpatentable over Das et al. (http://www.ofsoptics.com/resources/documents/coarsewdm_20gb.pdf, August 2001) in view of Chraplyvy et al. (US Patent No. 6205268).

Regarding claim 4, Das et al. disclose the system of claim 1, but do not disclose specifically that the wavelength coverage for the entire band is from 1300 to 1700 nm. However, Das et al. do disclose CWDM use of the "entire optical spectrum" of an optical fiber, specifically 1260nm to 1625nm (page 1444, Abstract paragraph). It would have been an obvious design choice to one of ordinary skill in the art at the time of the invention that the "entire optical spectrum" could have alternatively been 1300 to 1700 nm, as the range that defines the "entire optical spectrum" is an inherent characteristic of the optical fiber used. Das et al. disclose that each laser has a unique wavelength in this range and the space for any two adjacent channels is 20 nm. Das et al. do not disclose the space for any two adjacent channels is 6 nm. Chraplyvy et al. disclose a broad spectrum WDM system with wavelength spacing of 0.8 nm, but that the spacing may be greater or smaller depending on the network designer's considerations of amplifier bandwidth and availability and/or cost of components such as multiplexers and demultiplexers (col. 4, lines 16-21). It would have been obvious to one of ordinary skill in the art at the time of the invention to use channel spacing of 6 nm if the network design budget and availability allowed for this spacing, as opposed to the wider spacing of Das et al., in order to provide the advantage of more channels and higher overall transmission bandwidth for the WDM system.

Regarding claim 6, Das et al. disclose the system of claim 5 but do not disclose first and second stages of multiplexing and demultiplexing, where with laser amplifiers between the first and second stages. Chraplyvy et al. disclose a WDM system with multiple stages of

multiplexing (fig. 1), with different amplifier types between the multiplex stages for amplifying the different wavelength ranges in the optical spectrum (col. 4, line 66 to col. 5, line 2), and the option of semiconductor amplifiers in between each stage (col. 5, lines 11-14). It would have been obvious to one of ordinary skill in the art at the time of the invention to use the cascaded multiplex/amplify/multiplex teaching of Chraplyvy et al. in the system of Das et al., in order to provide efficient choice of amplifiers for each wavelength range in the spectrum (for example, EDFA amplifiers are more cost effective than Raman amplifiers, but are primarily limited to the 1550 nm range).

Regarding claim 8, the combination of Das et al. and Chraplyvy et al. disclose that the band and bandwidth of each semiconductor laser amplifier in claim 6 is optimized and selected such that each amplifier for its small band covers the amplification for this small band (Chraplyvy et al.: col. 4, line 66 to col. 5, line 2).

Conclusion

13. Any inquiry concerning this communication from the examiner should be directed to N. Curs whose telephone number is (571) 272-3028. The examiner can normally be reached M-F (from 9 AM to 5 PM).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Jason Chan, can be reached at (571) 272-3022. The fax phone number for the organization where this application or proceeding is assigned is (703) 872-9306. Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (571) 272-2600.

Hanhphan
Hanh Phan
Primary Examiner
11/26/04

Notice of References Cited	Application/Control No. 10/041,064	Applicant(s)/Patent Under Reexamination YU, JIN	
	Examiner Nathan Curs	Art Unit 2633	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-6,205,268 B1	03-2001	Chraplyvy et al.	385/24
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	http://www.ofsoptics.com/resources/documents/coarsewdm_20gb.pdf (August 2001)
	V	http://www.ofsoptics.com/resources/documents/economics_wdm_20.pdf (August 2001)
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Economics for Choosing a Coarse WDM Wavelength Grid

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Abstract

This paper reviews grids of wavelengths suitable as standards for Coarse WDM (CWDM) optical communications networks. One of these is an extension of a proposal to the IEEE P802.3ae 10GbE standards. CWDM transmission is increasingly gaining popularity in applications such as metro access, 10 GbE, CATV, FTTH-PON, and other short-haul point-to-point systems with protocol-transparent services such as ESCON, FICON, and Fast Ethernet.[1] CWDM has the advantage of being a low-cost entry point into WDM with earlier prove-in than DWDM. In CWDM, the optical sources may drift to any value within a prescribed range that is on the order of several nanometers, since the sources are typically laser diodes that are not actively cooled to control temperature. Wavelengths have been chosen to accommodate the expected manufacturing variations and environmental thermal variations. Economics enters into the choice of grid from trading off specifications of filters and sources against capacity, and from conformance to the embedded base of source wavelengths already available. Filter and source economics drive the optical channel spacing wider, but the trend weakens beyond 20 – 25 nm. Overall system economics, in the outside plant in particular, favor as many optical channels as possible and so favor both closer channel spacing and use of the entire optical spectrum. These considerations lead to the conclusion that CWDM transmission is optimized by a channel spacing of about 20 to 25 nm across all optical fiber spectral bands from 1260 nm to 1625 nm. We present two grids based on these conclusions, one an extension of the IEEE 10GbE proposal, and discuss their respective advantages.

Introduction

Stabilizing the wavelength of emissions from a laser for Dense WDM applications typically requires that its operating temperature be stabilized. A thermoelectric cooler (TEC) is used to absorb the power dissipated by the laser. TECs and their control circuitry not only add cost to terminals, but also consume and dissipate power.

The cost of terminals in short-haul communications systems such as metro systems and LANs is more critical than in long-haul systems. This trend is especially true for very short-haul LANs where to reduce the terminal cost one employs strategies such as using Fabry Perot lasers. For transmission distances not quite so short, terminal costs can be reduced by eliminating the TECs while retaining a DFB-source architecture. As VCSELs mature, they may become a preferred choice as a source for many applications. For both DFBs and VCSELs, emitted wavelengths will drift with ambient temperature changes so that a range of spectrum must be set aside for each optical channel to accommodate drift. The wavelength grid proposed here is made out of such wide-enough spectral channels placed side by side. Because of the coarse spacing of these channels, we use the term Coarse WDM (CWDM) for these grids. CWDM is also being proposed for adoption by the ITU as the terminology to apply to WDM components designed for use in a range of channel spacing that includes 20- and 25- nm spacing.[2]

Economic Strategies and Modeling

The more channels, the more the capacity supported by each fiber. This reduces the number of fibers needed for a given application and provides a concomitant reduction in outside plant costs.[3 4] One way to increase the number of channels is to increase the overall extent of spectrum. For this reason, we propose a grid that covers all bands of the single mode optical fiber spectrum from 1260 nm to 1625 nm (see Figure 1). With the commercialization of low water peak fibers (LWPF) such as AllWave™ fiber from Lucent Technologies, this is now a practical strategy. Commercialization of the E-Band, the band that includes the water peak, is growing, as evidenced by (i) rising attendance at the 1400 nm Commercial Interest Group meetings, (ii) both domestic and foreign applications at 1400 nm by Canoga Perkins, (iii) and a substantial and accelerating deployment for the aforementioned AllWave fiber that is building an embedded base of low water peak fibers. Also notable, testing methodologies for the water peak region are offered by both Agilent and EXFO.

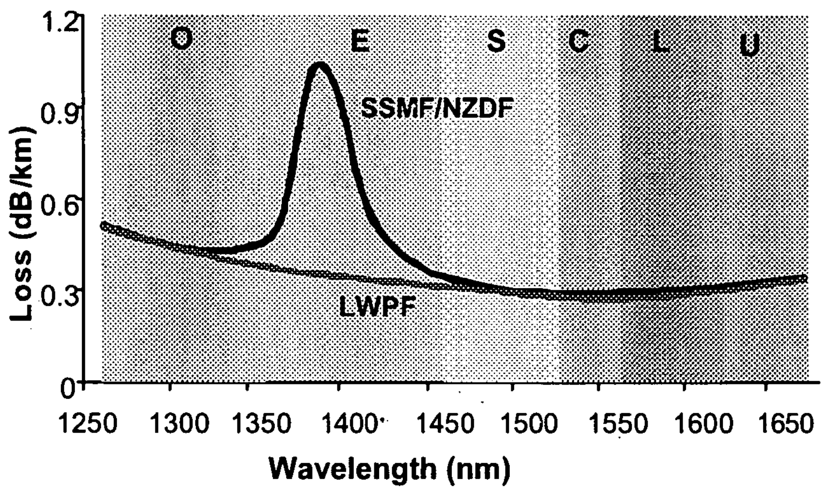

Figure 1. Fiber transmission loss in various wavelength bands.
LWPF enables CWDM across the entire single mode fiber spectrum.

The thermal drift of both DFB lasers and VCSELs is on the order of 0.1 nm/°C and is independent of the emitted wavelength. Since these are the two likely candidates for uncooled sources, this property makes it advantageous to specify channels by wavelength rather than by frequency as is done for DWDM.[5]

Another way to increase the number of channels is to make each channel narrower. There are limits to this direction. Once a range of ambient operating temperatures and once manufacturing tolerances on 25°C laser wavelengths are defined, the minimum spacing of channels is determined.

Economics enter by considering how the costs of lasers and filters vary with channel spacing. Laser costs decrease as production tolerances on 25°C wavelengths are relaxed and production yield increases. Relaxed 25°C tolerances mean wider channel spacing. Thin film filter (TFF) costs increase as their Figure of Merit (FOM), the ratio of passband width to skirt width, increases, since more layers are necessary. So for a given passband, filter costs decrease as the channel width increases. These trends have been analyzed with a model to understand laser and filter costs as a function of spacing. Relative costs for lasers were based on yield given a Gaussian wavelength distribution for laser wavelength variation in

production. For filters, an empirical power law cost model fit current commercial prices reasonably well. Filter passband requirements were based on a 100°C total variation in ambient temperature for the laser. Prices were also used to weigh the relative contribution of filters and lasers. Cost trends for both lasers and filters drive cost per channel down with increasing channel spacing.

We see in Figure 2 that the rate at which cost decreases levels off in the range of 20 to 25 nm. Shown are relative total costs for mux and demux filters, plus an uncooled DFB 2.5 Gb/s laser. Each plot is for a different manufacturing tolerance on room temperature laser wavelength. As this tolerance is relaxed, laser yield and cost decreases but there is a resulting stricter requirement on the FOM for the filters

But wider channels also mean fewer channels with economic consequences to outside plant materials costs by the need for more fibers for a given capacity. In the range of 20 to 25 nm we have reached the point of diminishing returns for increasing channel width.

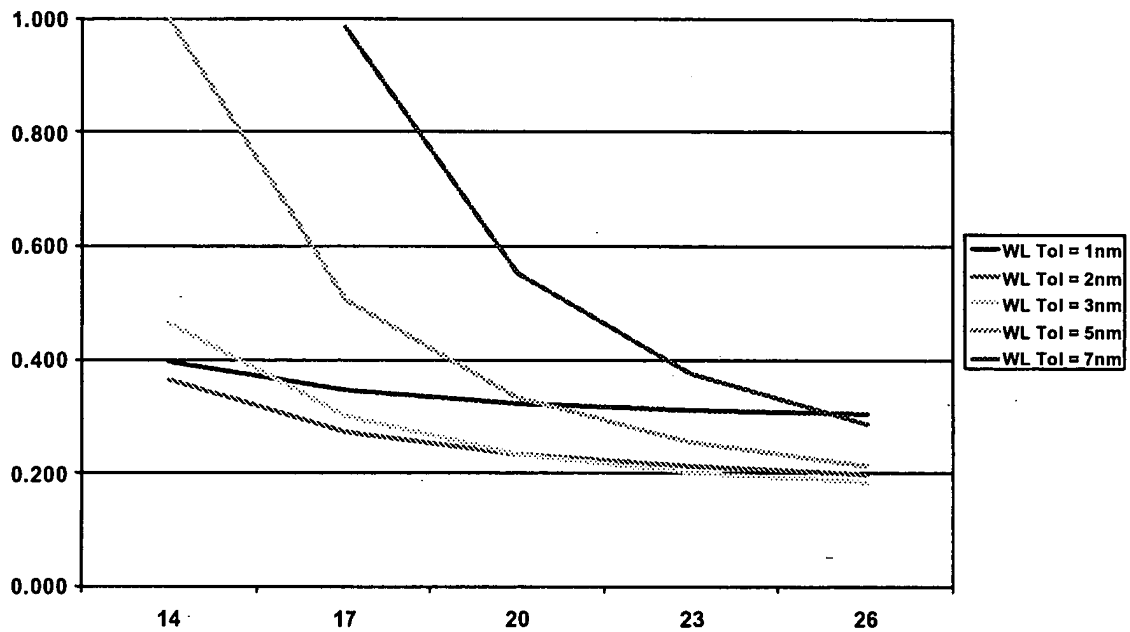

Figure 2: Relative Variable Total Costs for mux and demux filters plus an uncooled 2.5 Gb/s DFB laser source plotted for various laser production tolerances.

Economics also enter into the choice of specific center wavelengths for the transmission channels. Sources with a history of established production benefit from not needing to climb a production learning curve, and from economies of scale. Various wavelengths, such as 1310 nm, 1510 nm, and 1550 nm, are already available in uncooled packages. A wavelength grid that uses these would have the further time-to-market advantage that some of the wavelengths would be immediately available for applications.

A Metro CWDM Wavelength Grid

Given the considerations above, a wavelength grid is here presented as a prime candidate for consideration as a standard for CWDM systems. This grid incorporates the properties conducive to an economic CWDM grid:

- Channel widths of 20 to 25 nm, the narrowest channels before escalation of laser and filter costs,
- Full utilization of wavelength bands, O, E, S, C, L, from 1260 nm to 1625 nm to take full advantage of modern LWPF, and
- Employment of particular wavelengths that offer economies of scale and rapid utilization

The CWDM center wavelengths in each of the optical spectrum bands are:

O-Band: 1290, 1310, 1330, 1350 nm
E-Band: 1380, 1400, 1420, 1440 nm
S+C+L-Band: 1470, 1490, 1510, 1530, 1550, 1570, 1590, 1610 nm

Note that there is 30 nm spacing between 1350nm and 1380nm and again between 1440nm and 1470 nm. This allows the specification of guard bands to foster separate operation of the spectral bands by means of band-pass filters.

Metro Extension to an IEEE CWDM O-Band Proposal

A proposal for a CWDM grid that was submitted to the IEEE Task Force charged with 10 GbE standards (P802.3ae) should be noted. 10 GbE applications promise to create a high demand and economies of scale for whatever wavelengths are chosen for their use. A 24.5-nm grid was proposed within the "O" Band (1260 nm - 1360 nm) for G.652 fibers. Single mode transmission up to 10 km was proposed while multimode was proposed to 600 m. Four wavelengths were proposed: 1275.7, 1300.2, 1324.7, 1349.2 nm. To be consistent with this IEEE proposal, the following grid of wavelengths is offered here:

Wavelength Grid that incorporates the IEEE P802.3ae CWDM proposal:

O-Band: 1275.7, 1300.2, 1324.7, 1349.2 nm
E-Band: 1380, 1400, 1420, 1440 nm
S+C+L-Band: 1470, 1490, 1510, 1530, 1550, 1570, 1590, 1610 nm

This grid, if the O-band proposal is approved for 10Gbe, has the advantage of the high production one would envisage for 10GbE applications. The "E" and "S+C+L" spectra are common to both this grid and the first wavelength grid. One advantage of the first grid is the use of the 1310-nm center wavelength, where most O-band lasers are available today. Also, the first grid has a minimum channel center wavelength of 1290 nm to avoid the high losses from Rayleigh scattering at shorter wavelengths. At the 10-km maximum distances proposed to the IEEE, this is not a critical consideration. But such losses become increasingly important at the longer transmission distances of metro access networks in the range of 20 to 50 km. 1270 nm should be kept in reserve for where its increased loss is acceptable for particular applications.

References

[1] J.Petiote, *Low-cost components give coarse WDM an edge,* WDM Solutions (Supplement to Laser Focus), Jan. 2001.

[2] ITU G.671

[3] B. R. Eichenbaum et al, *Low Water Peak Fiber and Coarse WDM for HFC Baseband Digital Reverse Architectures ,* Proceedings SCTE Cable Tec Expo 2000

[4] B. R. Eichenbaum et al, *Opportunities for Revenue Enhancement and Cost Reduction in Metro Rings and Access Networks enabled by the Emerging Standard Low Water Peak Fiber and New Architectures,* Proceedings NFOEC 2000

[5] ITU G.692, and ITU G.959.1

COARSE-WDM THROUGHPUT OF UP TO 20 GB/S IN THE 1300-1440 NM REGION OVER 63 KM OF LOW WATER PEAK FIBER

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B. Eichenbaum, C. Joyner,(2) and L. Nelson(2)

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Introduction

Coarse-WDM (CWDM) transmission with uncooled laser diodes is increasingly gaining popularity in applications such as metro access, 10 GbE, CATV, Fiber-to-the-Home (FTTH) Passive Optical Network (PON), and other short-haul point-to-point systems with protocol-transparent services such as Enterprise Systems CONnection (ESCON), Fiber Channel and Gigabit Ethernet. Not only is CWDM more economical due to reduced cost of uncooled laser packaging [1] and relaxing of WDM filter specifications, it also helps lower laser transceiver power consumption by eliminating the need for a ThermoElectric Cooler (TEC). This can help reduce the size and power drain requirement of CATV mini-fiber nodes, which are often placed in outside plant environments with commercial feeds. Full Spectrum CWDM would use all wavelengths across the optical fiber single mode spectrum (1260 to 1625 nm) with approximately 20-nm channel spacing. Until recently, CWDM transmission in the 1350-1450 nm part of the spectrum was not practical due to the presence of the water peak at 1385 nm. However, with the advent of low water peak fibers (LWPF) such as AllWave®, one may now utilize the entire 1300-1460 nm spectral range encompassing the O- and E- Bands (in addition to extension up to 1620 nm and beyond). In this paper we report impairment-free CWDM transmission of multiple 2.5 Gb/s signals, from lasers spaced approximately 20 nm from each other in the 1300 to the 1440 nm spectral range, over 63 km of LWPF. When the full capability of 8 wavelengths is exploited, this system can transport 20 Gb/s.

CWDM and Fiber Characteristics

Figure 1 shows the attenuation and dispersion characteristics of a typical LWPF.[2] Basically, its dispersion profile is identical to standard single mode fiber (SSMF) across the entire transmission band. But its loss characteristics are far superior in the 1350-1450 nm region due to the elimination of the 1385 nm water peak. Removal of this water peak allows use of the low-dispersion 1400 nm region (average dispersion D≈8 ps/nm-km). For the first time transmission in the entire 1260 to 1620 nm region is feasible, increasing the usable WDM spectral capacity by ≥ 50% compared to SSMF. The loss for LWPF is specified at ≤ 0.35 dB/km @ 1385 nm, although the typical loss value is smaller. Since span engineering is carried out with fiber loss value at the lowest wavelength supported (where Rayleigh scattering floor is higher), the 0.35 dB/km loss specification at the water peak therefore is no worse than the typical fiber loss at 1310 nm. A quick survey of most directly modulated laser diodes available in the

O-band and the emerging E-band indicates [3] they will be attenuation, not dispersion, limited at 2.5 Gb/s.

We note another important fiber characteristic, effective area A_{eff}, which determines the nonlinearity threshold of a fiber. A small A_{eff} may be beneficial for distributed Raman amplified systems but detrimental due to (i) higher four wave mixing (FWM) for closely spaced WDM channels, and (ii) Raman cross-talk for channels separated by about 100 nm. Both LWPF and SSMF have a larger A_{eff} than non-zero dispersion shifted fibers, and consequentially reduced FWM and Raman crosstalk in CWDM systems.[2]

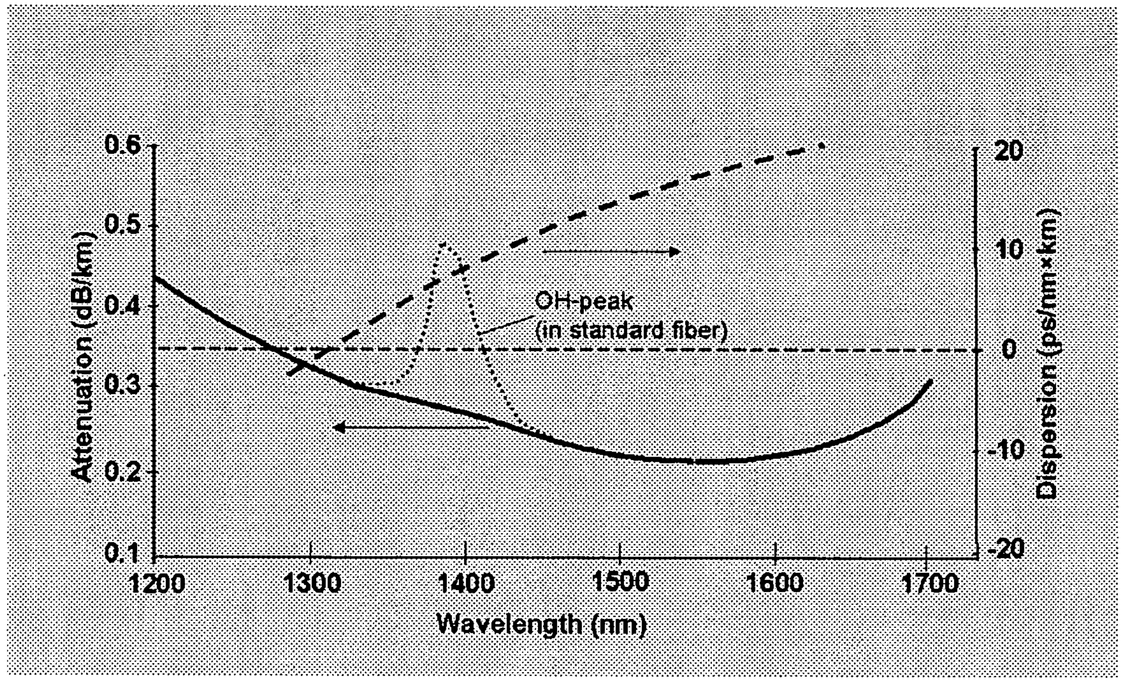

Figure 1: Attenuation and dispersion of LWPF.[2]

Generic CWDM Architecture

Figure 2 shows a generic CATV digital reverse architecture where the Node aggregates analog traffic from 600 fiber HouseHolds Passed (HHP) in the 5-40 MHz return band. This traffic is digitized via 12- or 14- bit A/D sampling at a sampling frequency of 100 MHz to form a baseband 2.5 Gb/s NRZ (non return-to-zero) signal for transport to the Primary Hub over fiber. As many as 8 (or a maximum of 16) fiber tributaries are passively multiplexed at the Secondary Hub for backhaul to the Primary Hub. The CWDM signal is demuxed and regenerated at the Primary Hub. While the schematic shows all WDM filters co-located at the node, in the future these filters can be distributed among a daisy chain of 8 smaller (75 HHP) nodes as envisioned in AT&T's OXIOM™ architecture in order to increase the reverse bandwidth per subscriber eight-fold.[4]

Although CATV nomenclature is used, this schematic is generic in that it applies to FTTH-PON or a metro access ring with OADM, as well. An end-to-end link budget of about 32 dB (TX output=0 dBm modulated, receiver sensitivity of –32 dBm @ 10^{-9} @ 2.5 Gb/s) would yield a fiber reach of 60 km (24 dB link loss @ 0.4 dB/km @ 1290 nm) with assumed 7 dB mux-AND-demux loss (16 ports) and 1 dB

margin. Fortunately, one need not allocate any dispersion penalty margin typically incurred at 1550 nm regions, since these will be offset with reduced fiber loss (typically 0.25 dB/km at 1550 nm). A reach of 60 km is expected to cover more than two-thirds of CATV, PON and metro access applications. A longer reach can be obtained by using higher output lasers (or semiconductor optical amplifiers), or restricting total mux/demux ports to 8.

The eight CWDM wavelengths can be spaced in a 20 nm grid, starting at 1300 nm and ending at 1440 nm, with a 13 nm passband each to account for laser thermal drift.[5] The 8×1 Mux and 1×8 DeMux use low-loss thin-film filter technology that can be easily scaled to larger number of wavelengths (up to 12 in SSMF and up to 18 in LWPF) without service interruption. The CWDM mux/demux costs are expected to be significantly lower than DWDM mux/demux costs due to passive vs. active alignment.[6] Additionally, CWDM filter Figure-Of-Merit (FOM) requirements for a given isolation are expected to be more relaxed than for equivalent DWDMs. Or, from another perspective, for a given FOM, CWDM yields greater isolation so that thin-film filters need not be cascaded (as is required in current DWDM systems [7]) resulting in further reductions in costs.

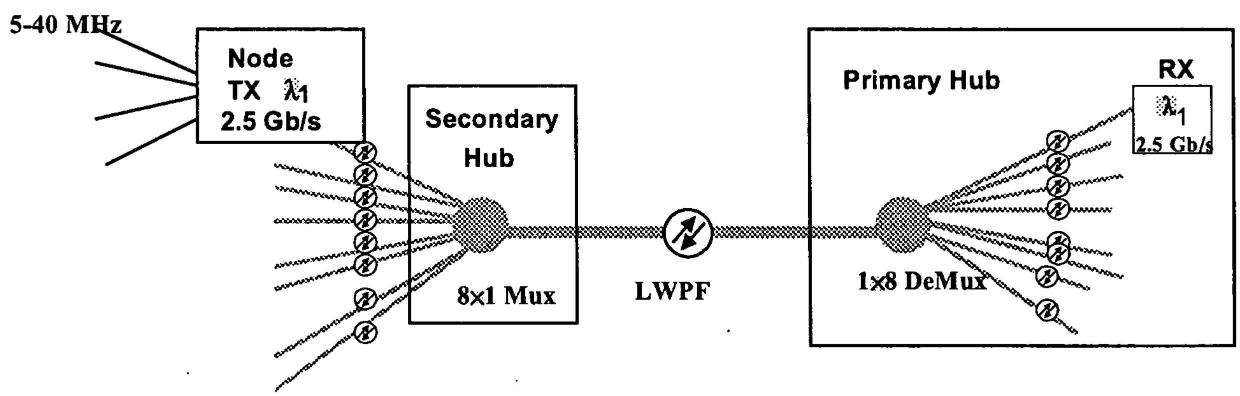

Figure 2: CATV Digital Reverse using CWDM with 20 Gb/s throughput

Experiment, Results and Discussions

We multiplexed the outputs of three 2.5 Gb/s NRZ modulated lasers (1360 nm, 1380 nm, 1400 nm), and three CW (continuous wave) lasers (1300 nm, 1320 nm, 1440 nm) with an 8-port CWDM passive multiplexer for transport over 63 km of Allwave® LWPF. The wavelengths were chosen to exhibit any CWDM related adjacent channel interference as well as potential Raman crosstalk.

Figure 3 shows the spectrum of the six transmitting lasers after 63 km of fiber. The 2.5 Gb/s modulated lasers at 1360, 1380 and 1400 nm were all received error-free after the fiber and the demux. The lasers emitted power in the 0 to +3 dBm range. Receiver sensitivity was approximately –28 dBm @ 10^{-9} BER. Maximum mux-plus-demux insertion loss was less than 4 dB in any wavelength region for these 8-port devices.

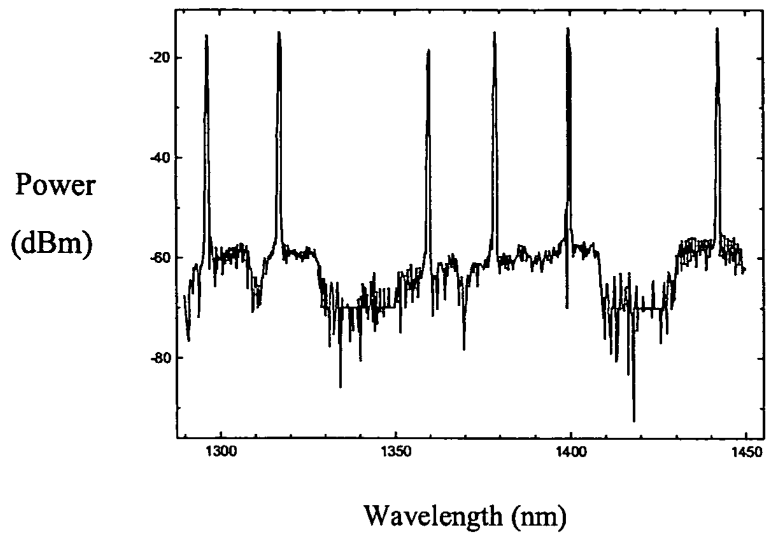

Figure 3: Spectrum of 6 lasers (3 CW, 3 modulated) after 63 km of LWPF. Resolution BW=0.5 nm.

Figures 4, 5, and 6 show the BER vs. sensitivity curves at 1360, 1380 and 1400 nm wavelengths respectively, for the cases of (i) back-to-back, (ii) after propagation over fiber and WDMs, (iii) fully loaded (i.e., transmission over fiber and WDMs with all the CW and adjacent channels powered up). The adjacent channel impairment is virtually non-existent, the slight degradation at 1400 nm for the case with transmission over fiber as compared to back-to-back results is probably due to dispersion. We checked for (potential) Raman crosstalk impairment from 1300 nm to the 1400 nm transmission and found none. Hence, this system can be readily expanded to an 8-wavelength system, transporting 20 Gb/s, with negligible loss of system margin.

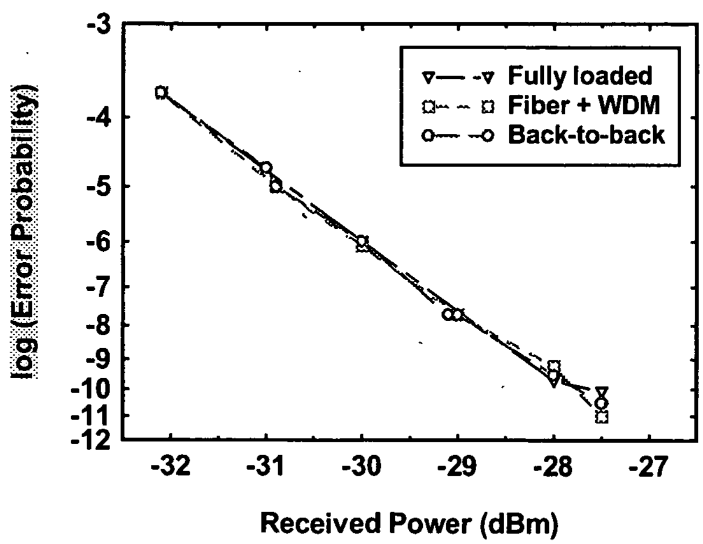

Figure 4: BER vs. power at 1360 nm, 2.5 Gb/s

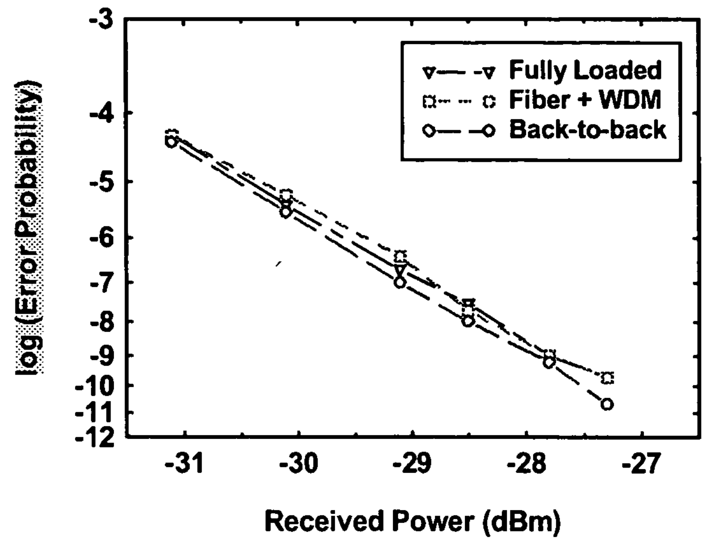

Figure 5: BER vs. power at 1380 nm, 2.5 Gb/s

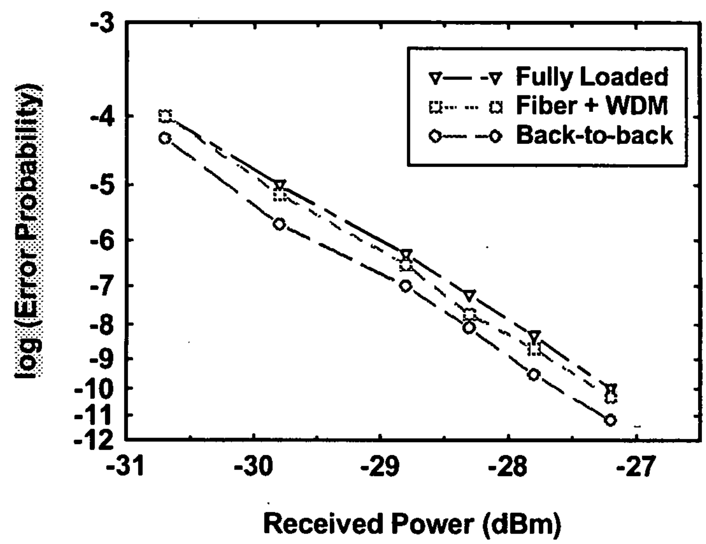

Figure 6: BER vs. power at 1400 nm, 2.5 Gb/s

In summary, we have demonstrated impairment-free transmission of CWDM signals in the 1300-1440 nm region, using low-cost uncooled lasers and CWDM thin film technology filters having the potential to be far more inexpensive than their DWDM counterparts. When extrapolated to the eight wavelengths supported by the mux and demux, a 20 Gbps throughput can be realized, transporting CATV digital reverse, OC-48, 10 GbE and (media access control) MAC-layer independent Ethernet-PON.[8] As the number of wavelengths migrate to Full Spectrum CWDM, greater cost savings are realized utilizing LWPF such as Allwave® (up to 18 wavelengths, though 16 is more likely,[5]), compared to SSMF which is limited to about 12 wavelengths. Synergistic with the 10GbE acceptance, we believe low cost VCSEL (vertical cavity surface emitting laser) technology [9] will enable such CWDM systems to be upgraded to 10 Gb/s per wavelength, for an aggregate 160 Gb/s, making them highly attractive for the enterprise and metro access markets.[10]

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References

[1] J.Petiote, "Low-cost components give coarse WDM an edge," WDM Solutions (Supplement to Laser Focus), Jan. 2001.

[2] S. Huensche, et al, "Multi-Services WDM Transmission in Zero-Water peak Fiber of Voice, Video & Data Services," NFOEC, 1999.

[3] NTT Electronics, "Optical Semiconductor Devices 2000," product data sheet.

[4] O. Sniezko, "Reverse Path for Advanced Services – Architecture and Technology," 1999 NCTA Technical Papers.

[5] B. Eichenbaum and S.K. Das, "Economics for Choosing a Coarse WDM Wavelength Grid," NFOEC, 2001.

[6] H. Spreckman, Tsunami Optics, private communication

[7] S. M. Mysore and O. Sniezko, "Effects of Crosstalk on Bi-Directional and Hybrid QAM/Digital DWDM Systems", 2001 NCTA Technical Papers.

[8] IEEE 802.3 Ethernet in the First Mile Study Group, http://www.ieee802.org/3/efm/index.html

[9] Press Release at OFC 2001, Anaheim, "Nova Crystals Demonstrates World's First 10 Gb/s surface emitting laser at 1310 nm," 3/19/01.

[10] R. Fang, "Wide-Space WDM in Metro Edge Networks," See http://www.fpnmag.com/exec/relpgm.exe??RPTID=SHOWPR?ACCT=0004297?ISSUE=0102?RELTYPE=TF?PRODCODE=0000?PRODLETT=A

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